Development of the Human Dentition

Development of the HUMAN DENTITION

Frans P.G.M. van der Linden, DDS, PhD
Professor Emeritus and Former Chair
Department of Orthodontics
Radboud University Nijmegen
Nijmegen, The Netherlands

Quintessence Publishing Co, Inc
Chicago, Berlin, Tokyo, London, Paris, Milan, Barcelona, Istanbul, Moscow, New Delhi, Prague, São Paulo, Seoul, and Warsaw

First published as *Gebitsontwikkeling bij de mens*, in Dutch in 2015 by Bohn Stafleu van Loghum, The Netherlands.

Library of Congress Cataloging-in-Publication Data

Names: Linden, Frans P. G. M. van der, 1932- , author.
Title: Development of the human dentition / Frans P.G.M. van der Linden.
Other titles: Gebitsontwikkeling bij de mens. English
Description: Hanover Park, IL : Quintessence Publishing Co., Inc., [2016]
|
Translation of: Gebitsontwikkeling bij de mens / F.P.G.M. van der
Linden.
Houten : Bohn Stafleu van Loghum, 2010. | Includes bibliographical
references and index.
Identifiers: LCCN 2016005916 | ISBN 9780867157253
Subjects: | MESH: Dentition | Maxillofacial Development | Tooth--growth &
development | Atlases
Classification: LCC QP88.6 | NLM WU 17 | DDC 611/.314--dc23
LC record available at http://lccn.loc.gov/2016005916

Quintessence Publishing Co Inc
4350 Chandler Drive
Hanover Park, IL 60133
www.quintpub.com

5 4 3 2 1

Editor: Bryn Grisham
Design/Production: Angelina Sanchez

Printed in the United States of America

Contents

Video Clips

The contents of this book are accompanied by 50 video clips that are referenced throughout the book. These clips can be accessed at: www.youtube.com/quintbook

Clip	Title	Duration (min:sec)
1	Tooth Development	3:53
2	Formation of Mandibular Molar Crown	0:58
3	Formation of Mandibular Incisor	0:19
4	Formation of Mandibular Canine	0:19
5	Formation of Mandibular Molar	0:24
6	Formation of Mandibular Incisor, Canine and Molar	0:22
7	Eruption and Transition of Central Incisors with Surrounding Soft Tissues	0:20
8	Transition of Mandibular Incisors with Moderate Space	0:19
9	Transition of Maxillary Incisors with Moderate Space	0:12
10	Transition of Mandibular Incisors with Excess of Space	0:21
11	Transition of Maxillary Incisors with Excess of Space	0:18
12	Transition of Mandibular Incisors with Shortage of Space	0:20
13	Transition of Maxillary Incisors with Shortage of Space	0:21
14	Changes of Maxillary Permanent Incisors After Extraction of Deciduous Canines in Anterior Crowding	0:30
15	Transition of Mandibular and Maxillary Incisors with Moderate Space	0:20
16	Transition of Canines and Premolars with Excess of Space	0:15
17	Transition of Canines and Premolars with Moderate Space	0:16
18	Transition of Canines and Premolars with Shortage of Space	0:17
19	Eruption of Second Permanent Molars	0:15
20	Eruption of Third Permanent Molars	0:18
21	Movements of First Permanent Molars	0:20
22	Rail Mechanism	0:17
23	Eruption Rate and Reduction of Eruption by Force Application	1:43
24	Resorption of Deciduous Molar Associated with Eruption of Premolar	0:14
25	Rotating Overview of Developing Dentition	1:39
26	Cone-Funnel Mechanism	0:49
27	Diagnosing Anterior Forced Bite Component in Mild Class III Malocclusion	0:14
28	Normal Tooth Mobility	0:19
29	Excessive Tooth Mobility Caused by Periodontal Breakdown	0:17

Preface

Learning about the development of the dentition is an essential part of the education of dentists, orthodontists, pedodontists, and dental hygienists, nurses, and assistants. To be able to determine if development is deviant, one has to be familiar with the variations that lead to an optimal result. Indeed, normal development must be learned before deviations can be understood.

In a dental practice, one is often confronted with the complex aspects of the development of the dentition. These aspects are easier to understand when insight is gained into how certain processes work and why. Such an insight facilitates comprehension of the large diversity typically found in the development of the dentition. In addition, knowledge of interactions between the growth of the face and functions of the orofacial region is essential for understanding the development of the dentition.

This book deals with tooth formation, development of the deciduous dentition, the transition, the changeover to the permanent dentition, and the aging of the dentition. Much emphasis is paid to the relationship and reciprocal influence of the development of the dentition with the growth of the face and with functional factors. Subsequently, the development of orthodontic malocclusions is presented, followed by the effects of untimely loss of deciduous teeth.

For the composition of this book, the work *Development of the Dentition*—published in 1979 in Dutch, in 1983 in English, and subsequently in other languages—served as a model. The information that has become available since its publication is incorporated in this volume. However, new information in this field is scarce. For the last few decades, growth studies involving invasive methods such as radiographs are not allowed. At the same time, analysis of the development of the dentition on skulls has diminished as the export of skeletal material from the Asian countries that previously provided it has been banned. Nevertheless, the picture of the normal and deviating development of the dentition has become quite clear and rather complete. Furthermore, the development of the dentition has not changed over the years and will not do so in the future.

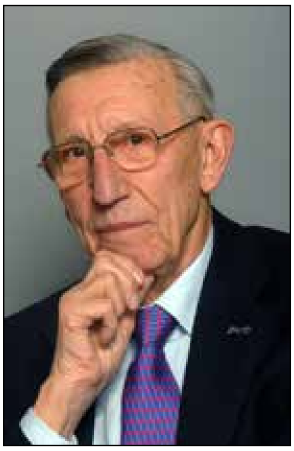
The need for a new edition arose partly from the desire to update the presentation of the information. Two-dimensional illustrations do not adequately represent the spatial conditions or the relationships among the permanent teeth and their predecessors. Furthermore, the relationship between the size of the teeth and the dimension of the surrounding bony structures is not clear, nor are the differences between the maxilla and mandible. To facilitate three-dimensional understanding, digital illustrations have been included, derived from the six-DVD series *Dynamics of Orthodontics*, which was produced by Quintessence under chief editorship of the author. Also derived from this DVD series are the 50 animated video clips that accompany the text and figures to illustrate the development of the dentition. In addition to many line drawings, a large number of photographs of skeletal material are incorporated from the volume *Development of the Human Dentition: An Atlas* (Harper & Row, 1976), co-authored by the author and Herman S. Duterloo.

Acknowledgments

The author was privileged to serve from 1962 until 1995 as the first professor and chair of the Department of Orthodontics of the Radboud University Nijmegen, where excellent conditions were provided to create high-quality education of dentists and orthodontists. Serving as a teacher was a fruitful learning experience, and the contact with students was a continuous source of inspiration and stimulation. In addition, ideal facilities were available for basic and applied research. A national grant made it possible to carry out the Nijmegen Growth Study, a mixed longitudinal study of 486 children, covering the period from 4 to 14 years of age. In addition, more than 100 skulls, which demonstrated the normal development of the dentition as well as the development of malocclusions, could be collected and analyzed. The information obtained from these two investigations served as an important resource for the contents of this book. The results of the University of Groningen School Study and The University of Michigan Elementary and Secondary School Growth Studies, in which the author was involved, also provided a wealth of information.

Several people have contributed to this edition. Drs H. S. Duterloo, J. C. Maltha, G. J. H. Schols, and M. G. Ackermans critically read the manuscript and provided suggestions for improvement. The photographs of the skull material were made by J. L. M. van de Kamp and H. A. W. Bongaerts. The thousands of dental casts of the Nijmegen Growth Study were made by or under the supervision of J. J. W. Siepermann and B. F. Bouwman. Most of the line drawings were made by hand 40 years ago by H. Reckers. More than 550 digital illustrations, derived from the series *Dynamics of Orthodontics*, were adapted by M. Mentz. The material for these illustrations was provided by A. Klebba and M. Hecklinger, who also put together the 50 incorporated animated video clips. M. J. Th. Cillessen-van Hoek took care of the manuscript, and Bryn Grisham edited the English book, while Angelina Sanchez was in charge of its design and production. The author greatly appreciates the professional input and pleasant and constructive cooperation of these individuals.

About the Author



Dr Frans P.G.M. van der Linden

Dr Frans P.G.M. van der Linden received his dental and orthodontic education at the University of Groningen, the Netherlands. In addition he studied orthodontics at the University of Vienna, Austria, and the University of Washington, in Seattle, Washington. From 1962 until 1995 he held the position of Professor and Chairman of Orthodontics at the Radboud University Nijmegen, the Netherlands. In 1969-1970 he served as the Netherlands Visiting Professor at The University of Michigan, in Ann Arbor, Michigan. In 1975 he became the first European to be certified by the American Board of Orthodontics.

Dr Van der Linden has a strong interest in education. He received a grant from the European Union to develop the curriculum with the chairpersons from 15 countries for a 3-year full-time postgraduate course in orthodontics; in 1992, this so-called Erasmus Programme became the international standard in the education of specialists in orthodontics.

Dr Van der Linden is particularly interested in incorporating basic and clinical research results in the theory and practice of orthodontics. He is an internationally recognized lecturer and has published more than 200 papers and a number of books. His main contribution is a series of six textbooks on orthodontics and dentofacial orthopedics. In addition, a practice-oriented book, *Orthodontic Concepts and Strategies*, appeared in 2004. Furthermore, Dr Van der Linden has been Editor-in-Chief and main author of the *Dynamics of Orthodontics*, an international multimedia project that presents the basic aspects of the field of orthodontics in six languages.

Dr Van der Linden's long-lasting activities in research and teaching have been widely recognized, even outside the fields of dentistry and orthodontics. He is the first dentist to be elected, in 1992, to the Royal Netherlands Academy of Arts and Sciences, founded in1808 and consisting of 220 prominent scientists from all fields of arts and sciences. Moreover, in 1993 he received the Professor Lammers Prize from the Faculty of Medical Sciences at the Radboud University Nijmegen for his outstanding contributions in education and teaching. In addition, he received the 1998 Louis Ada Jarabak Memorial International Orthodontic Teachers and Research Award from the American Association of Orthodontists Foundation.

Author's Note on Terminology

There is large variation in the way teeth are defined. Many authors do not systematically use the same sequence in specifying teeth. In addition, some make use of popular scientific, nonvaluable terms, such as *upper* instead of *maxillary*. The terms *upper* and *lower* should only be used for indicating lips, not teeth. Teeth are placed in a jaw, and thus, the jaw should be specified first. The second differentiation regards the side, *left* or *right*. Third comes the number of the tooth. Finally, *deciduous* and *permanent* should be directly connected with the tooth involved.

So, teeth should be indicated in a standard way that follows a systematic sequence of relevance:

1. Jaw: Maxillary/mandibular
2. Side: Left/right
3. Tooth number: First/second or central/lateral
4. Deciduous/permanent
5. Tooth

Indeed, preference is given to using the correct anatomical descriptions. Therefore, not *upper* or *lower*, but *maxillary* and *mandibular*. Not *cuspid* but *canine* (cuspid is also used for having a cusp). Not *bicuspid* but *premolar* (some premolars have 3 cusps). Not *wisdom tooth*, but *third molar*. Not *primary* but *deciduous* (there are no secondary teeth). *Deciduous* or *permanent* should be placed directly in front of the tooth type because that belongs together and is the most essential specification.

Some examples of the correct tooth terminology used in this book include, maxillary right central permanent incisor, mandibular left deciduous canine, maxillary right second deciduous molar, and mandibular left first permanent molar.

1

Formation of Teeth

Initial Stages of Formation

Teeth arise from the interaction of two germ layers, the ectoderm and the mesoderm. The ectodermal tissue provides the enamel, the mesodermal tissue the dentin.

The first local changes leading to the formation of teeth occur in the 6th week after conception. At that time, the oral cavity is formed and covered with a two-layer epithelium with still-undifferentiated mesenchyme underneath. Between the two layers lies the basal membrane, which facilitates the communication between the two types of tissue.

At the location of the future dental arches, the epithelium thickens, and the dental lamina develops. At every location where a tooth has to appear, the ectoderm of the dental lamina bulges into the mesenchyme. The initial shape of the crown is formed by local differences in mitotic activity (differential proliferation) of the epithelium and mesenchymal tissue. The basal membrane is situated at the future enamel-dentin border. The mesenchymal cells at the inner side of the basal membrane differentiate into odontoblasts; the epithelial cells on the outer side differentiate into ameloblasts. These cells deposit dentin and enamel on the basal membrane and form the crown. Subsequently, the odontoblasts build up the dentin of the root. At the external side of the root, cementum is deposited by cementoblasts, which are differentiated from mesenchymal cells (Fig 1-1).

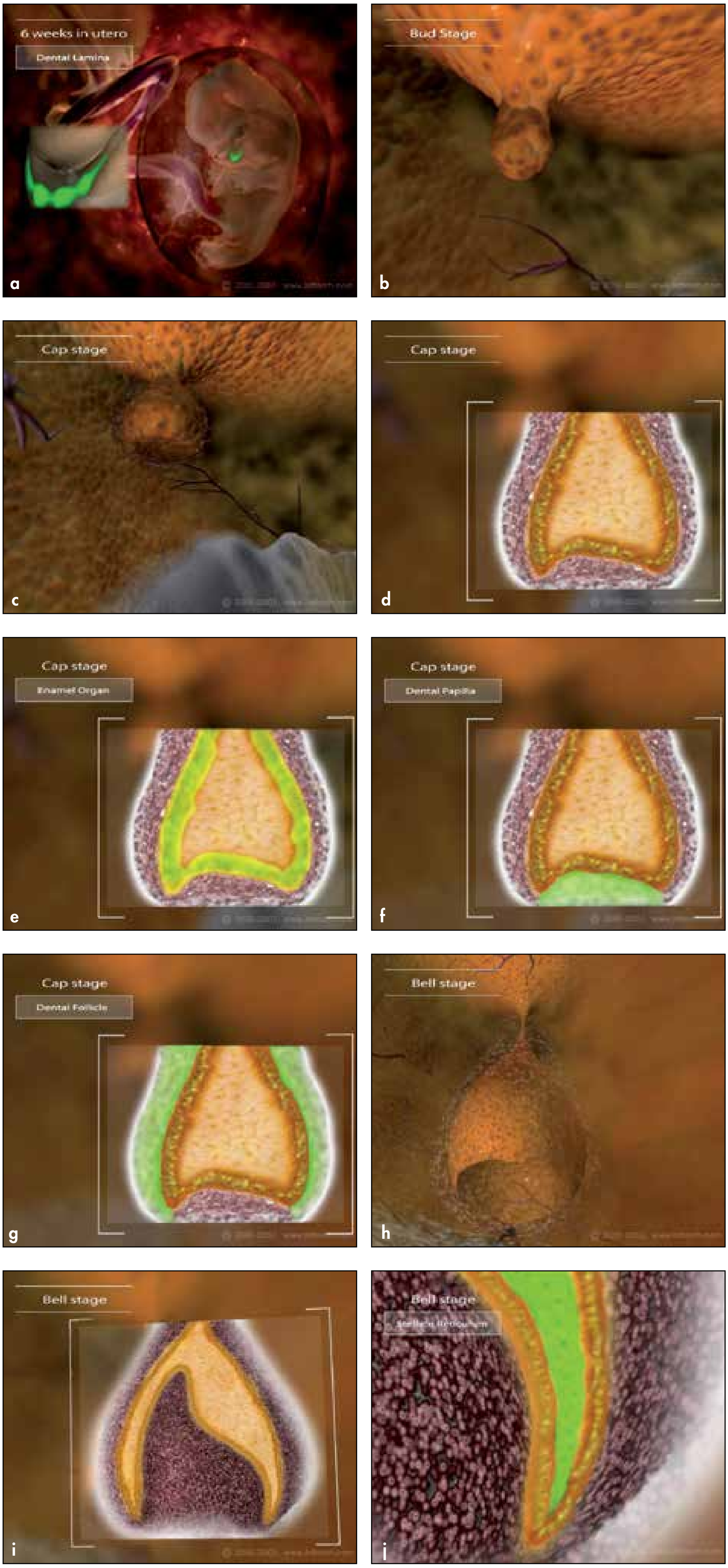
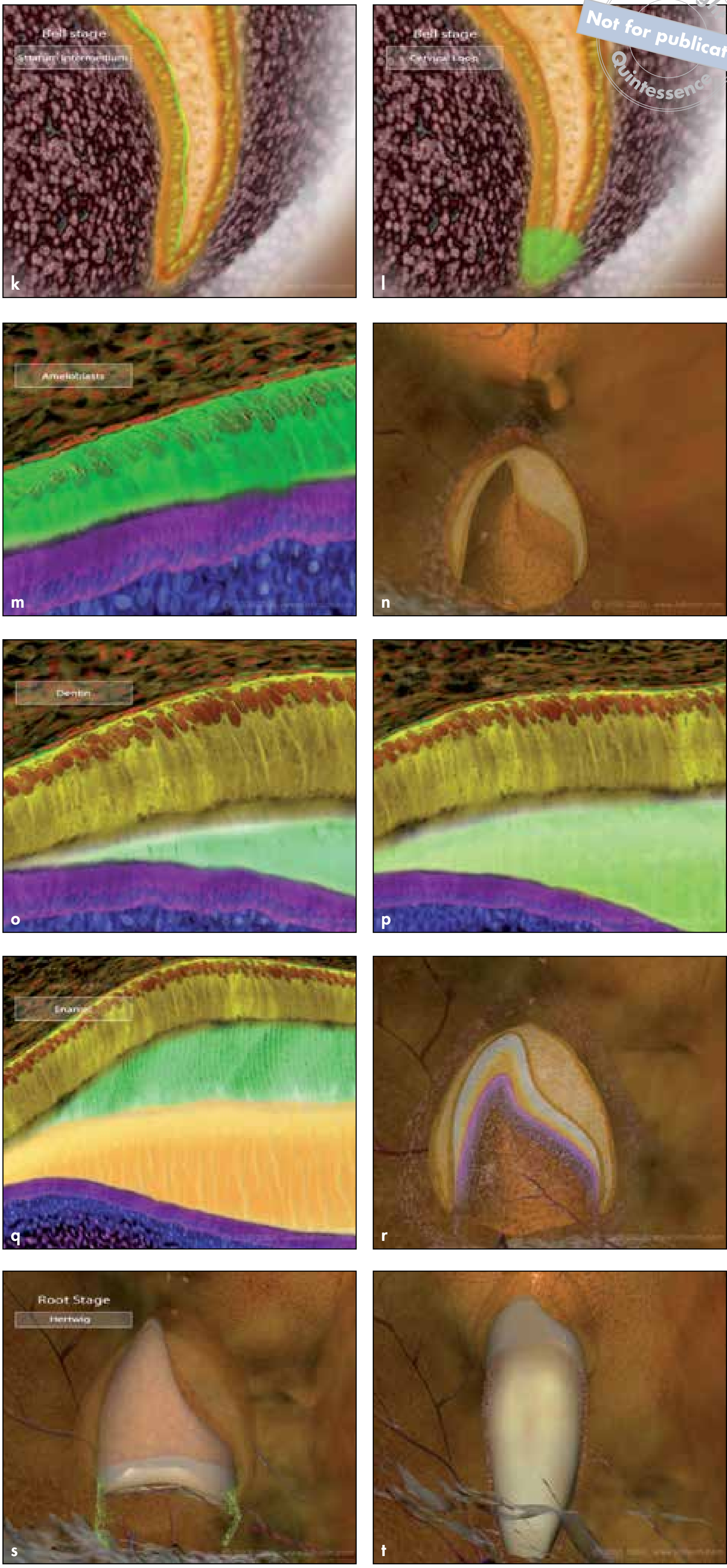


FIG 1-1 The form[illegible] decidu-ous incisor. *(a)* In the [illegible] conception, the oral epithelium thick-ens by differential proliferation at the location where the dental arches will arise. The dental lamina is formed. *(b)* At every location where a tooth has to be formed, the ectodermal tissue bulges into the mesenchymal tissue of the dental lamina, resulting in a tooth bud. *(c)* Extended growth of the epithelium of the tooth bud by differential proliferation results in a cap. *(d)* The cap will partially enclose a cell-dense mass of mesenchymal cells. *(e)* At the inner lining of the epithelial cap, the cells become cylindrically shaped. These are the preameloblasts, the precursors of the cells that later will deposit enamel onto the basal membrane. *(f)* The external surface of the cap continues to consist of cuboidal cells. Within the cap tissue, the stellate reticulum, a loose structure of mesenchymal cells, is formed. The cells at the periphery of the cell-dense mesenchymal mass become arranged along the basal membrane and differentiate into preodontoblasts. These are the precursors of the cells that will deposit dentin at the basal membrane. *(g)* The remaining part of the dental papilla differentiates into the pulp. The mesenchymal cells around the cap form the dental follicle, which later will lead to the formation of the periodontal ligament. *(h and i)* The total structure has attained a bell form. *(j)* Preameloblasts and the reticulum stellatum.

Fig 1-1 *(cont)* *(k)* A separate cell layer, the stratum intermedium, arises between the preameloblasts and the stellate reticulum. *(l)* At the edge of the cap, where the external layer becomes the inner lining, a cervical loop is formed. *(m)* Prior to the deposition of enamel and dentin, the basal membrane together with the preameloblast and preodontoblast layers have attained the form of the future crown. *(n)* Then the crown stage starts. *(o and p)* The preodontoblasts differentiate into odontoblasts that deposit the first dentin at the basal membrane. *(q)* Shortly thereafter, the preameloblasts differentiate into ameloblasts and begin to deposit enamel at the already formed dentin. The dentin is deposited in the direction of the basal membrane. During that process the odontoblasts migrate in the direction of the pulp, leaving odontoblastic processes behind in the dentinal tubules. The ameloblasts deposit enamel also in the direction of the basal membrane, but do not leave processes behind. *(r)* The enamel deposition continues until the crown is completely formed. *(s)* After the crown is finished, root formation starts. The tissue of the cervical loop proliferates further in an apical direction and forms the epithelial stocking that is called the Hertwig root sheath. *(t)* Pulpal cells become arranged at the inner side of the Hertwig root sheath and differentiate to preodontoblasts and subsequently to odontoblasts, which will deposit the dentin of the root. With the outgrowth of the Hertwig root sheath, gaps appear in its cervical part. Mesenchymal cells of the tooth follicle migrate through these openings to the root surface. Thereafter they differentiate to precementoblasts and further to cementoblasts, which deposit cement against the dentin of the root. See video clip 1. (Printed from van der Linden et al[1] with permission.)



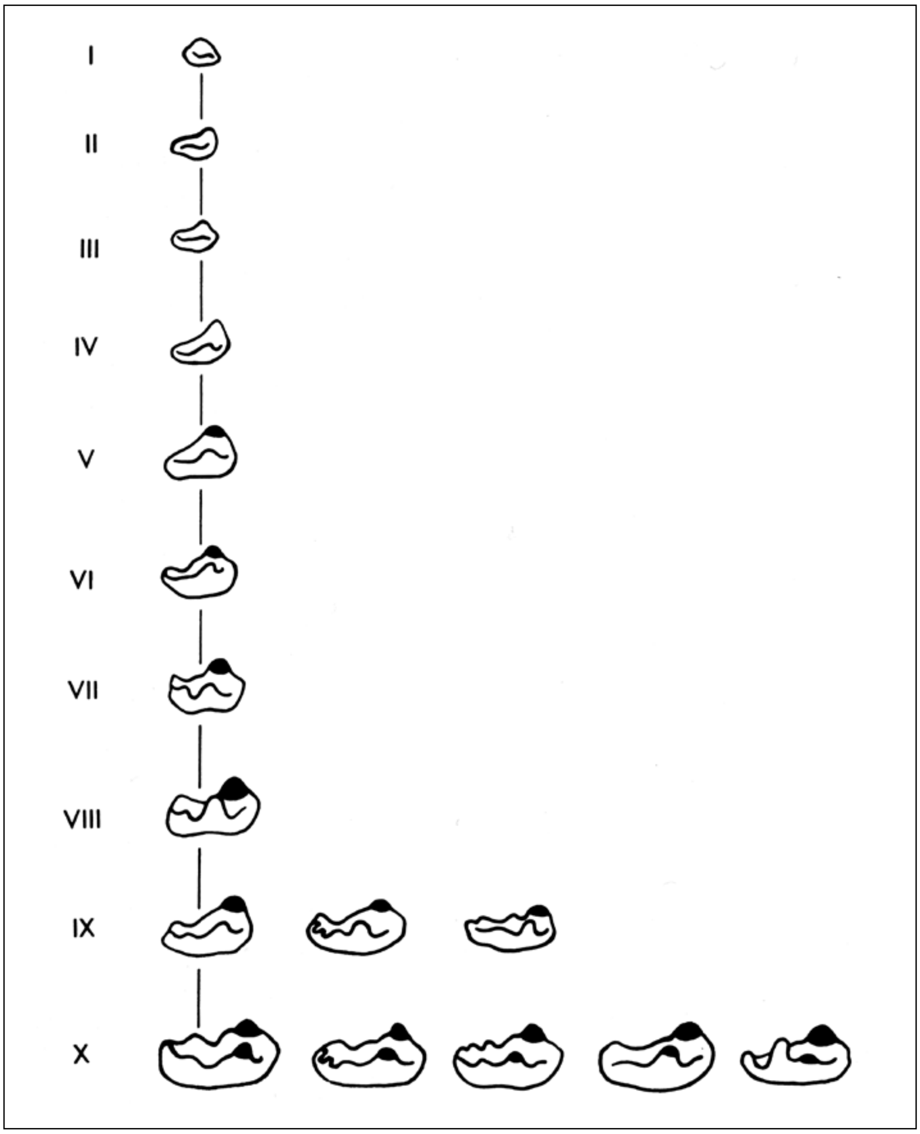


Fig 1-2 Developm[illegible] mandibular left first deciduous [illegible] vided in morphodifferential stage[illegible] From the first macroscopic indication of the formation of the molar, growth and morphodifferentiation occur (stage I). Mineralization at the first point starts at stage V, at the second point at stage X. Between stages V and X, the size of the future tooth crown increases substantially. The distances between the cusp tips continue to enlarge. From stage IX onward, individual differences in morphodifferentiation occur, resulting in variations in the morphology of the completed crowns. (Reprinted from Kraus and Jordan[2] with permission.)

Morphogenesis of Teeth

The morphogenesis of incisors, canines, and molars is essentially the same. Only the timing and form vary.[2]

Forming molars gradually increase in size by interstitial growth of the inner enamel epithelium. Mineralization starts at one future cusp tip (Fig 1-2). In a genetically determined sequence, ameloblasts and odontoblasts differentiate at other future cusp tips, followed by mineralization. Areas that are not yet mineralized can still increase in size. After the mineralizing fields have become connected (ie, coalescence), the distance between the cusp tips involved cannot increase further. Enamel deposition continues in the valleys between the cusp tips and at the circumference of the crown. After the entire circumference of the occlusal part of the crown is mineralized, only deposition of enamel at the circumference of the crown contributes to the increase in the mesiodistal and buccolingual dimensions (Figs 1-3 and 1-4).

The mineralization of incisors starts almost simultaneously at three locations and spreads horizontally. The mineralization of molars starts at the future cusp tips, one after the other with some time in between, and spreads under a sharp angle with the occlusal surface. Consequently, compared with molars, incisors establish more of their mesiodistal crown dimension at a relatively early stage. Subsequently, they only become wider by approximal enamel deposition.

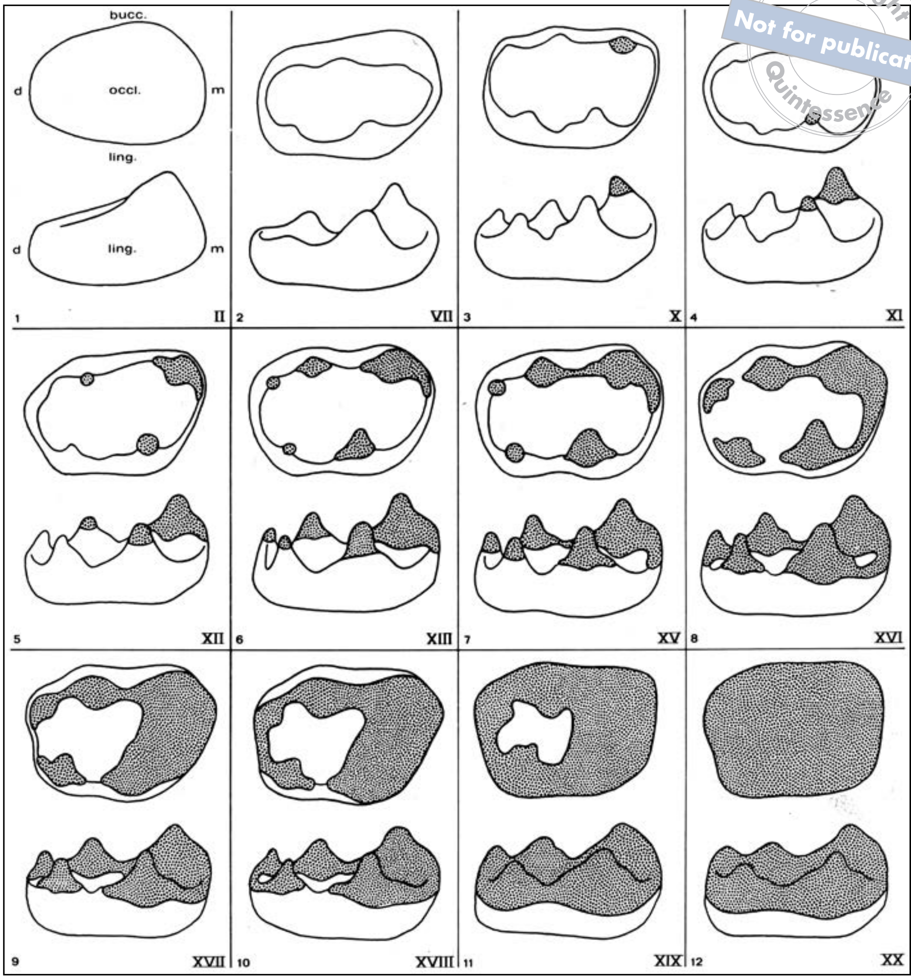


Fig 1-3 Changes in the morphology and the start and extension of the mineralization of a mandibular left second deciduous molar. All stages are presented at the same size, which obscures increases in dimensions (although they are comparable with those of the first deciduous molar in Fig 1-2). Mineralization of the second deciduous molar starts at stage X. In comparison with the first deciduous molar, morphodifferentiation has progressed considerably prior to the formation of predentin and enamel. At stage XV, the first coalescence takes place. At stage XVI, the mesial marginal ridge is established. At stage XVII, the distances between the distolingual, mesiolingual, and distobuccal cusp tips can still increase. At stage XVIII, the coalescence has progressed to the extent that the distances between the cusp tips cannot enlarge anymore. At stage XIX, the coalescence is established around the entire circumference of the occlusal part of the crown. At stage XX, the occlusal surface is fully mineralized. After stage XVIII, the circumference of the crown can increase only by apposition of enamel at its circumference. d, distal; bucc, buccal; occl, occlusal; ling, lingual; m, mesial. (Reprinted from Kraus and Jordan[2] with permission.)

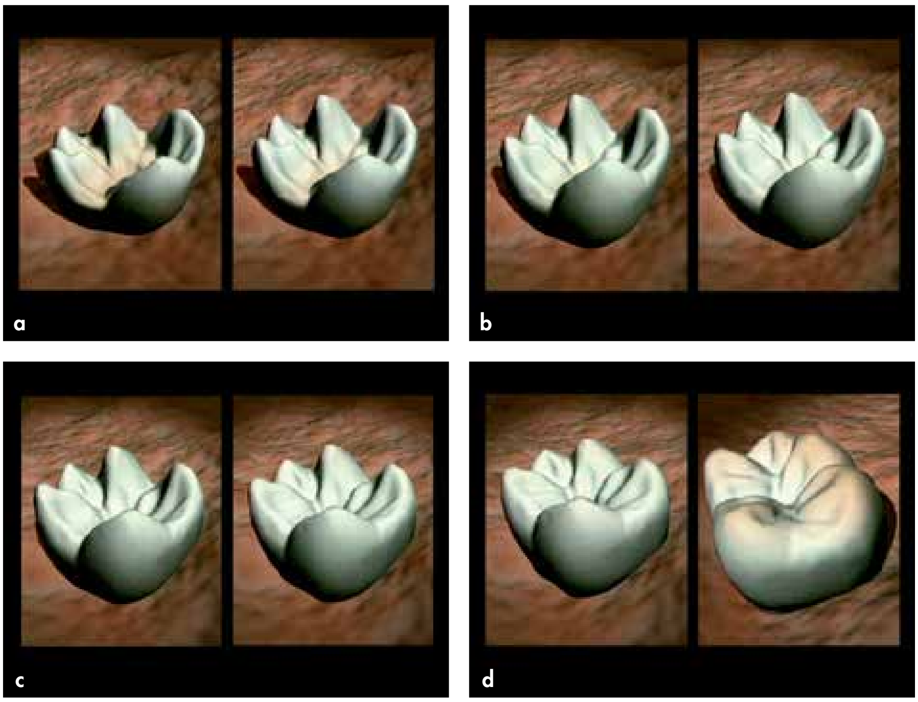


Fig 1-4 Formation of a mandibular first permanent molar observed from different directions. *(a and b)* Mineralization starts at the mesiobuccal cusp, followed successively by the other cusps. In the meantime, the slopes between the cusps become less steep. *(c and d)* Enamel is also deposited at the circumference of the crown, resulting in a slight increase in the mesiodistal and buccolingual dimensions. See video clip 2. (Printed from Van der Linden et al[3] with permission.)

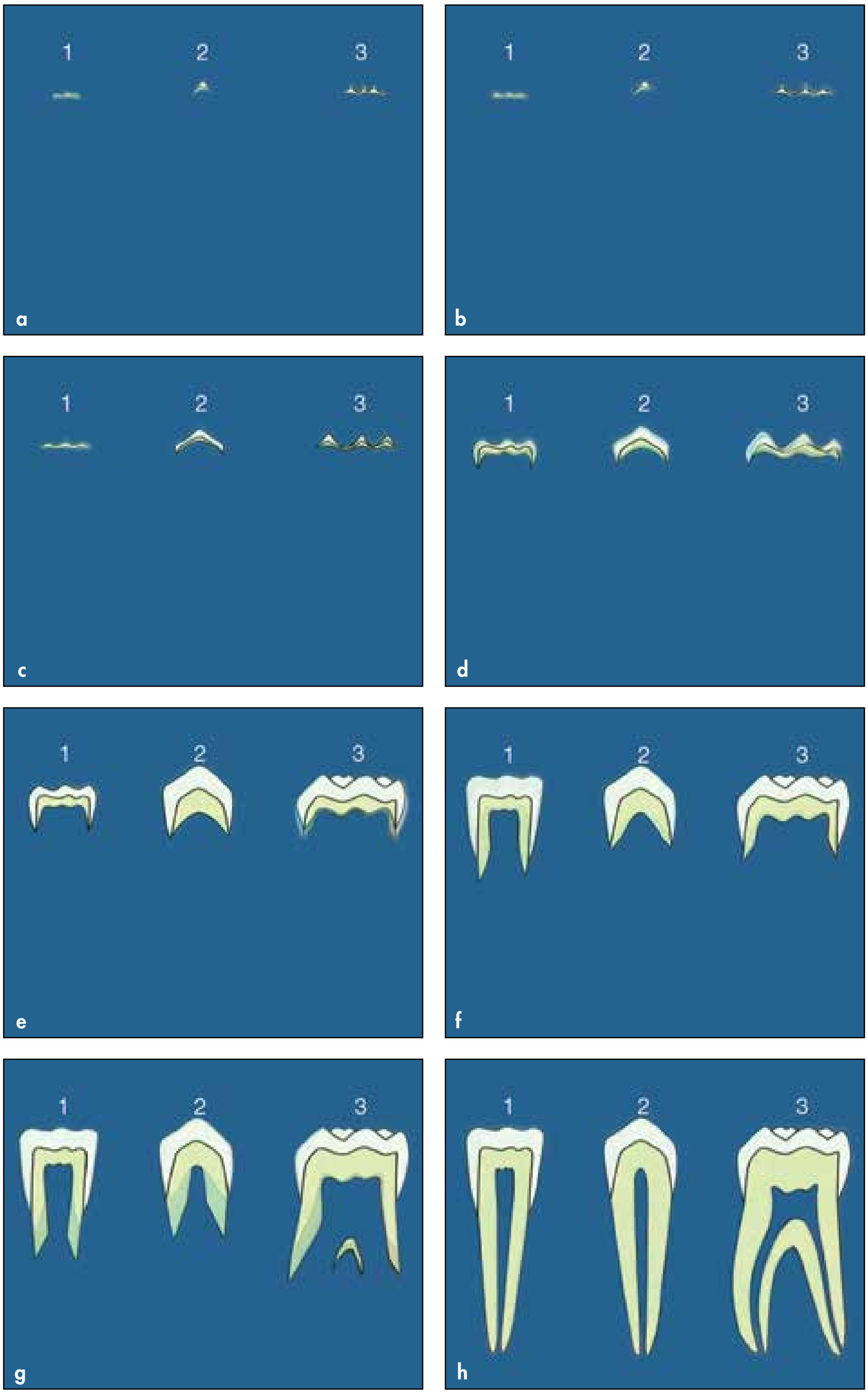
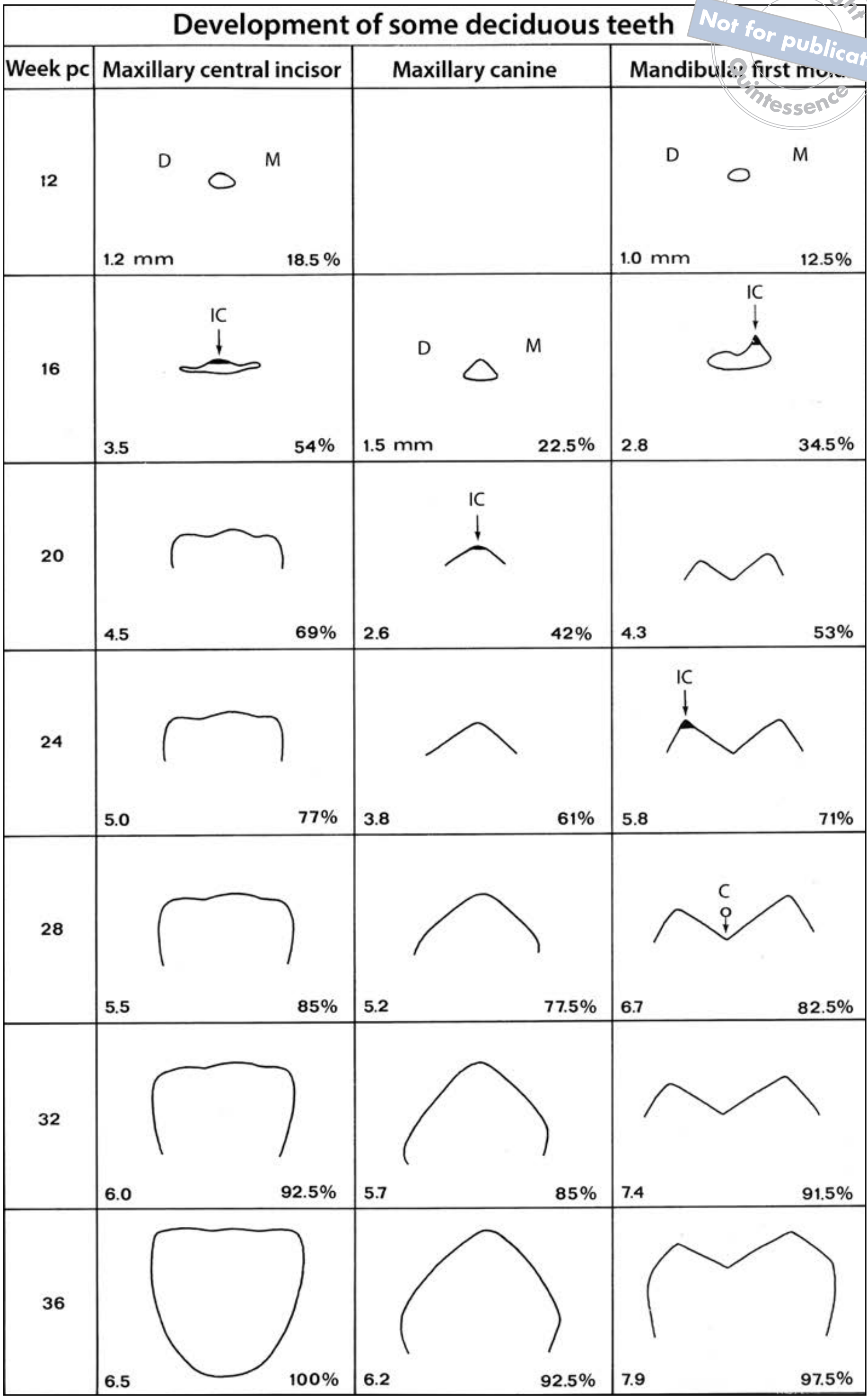


Fig 1-5 Formation of permanent teeth. *(a and b)* The mineralization of an incisor (1) starts at the middle of the incisal edge and shortly thereafter at two other locations more to the distal and mesial (the future mamelons). *(c and d)* The mineralization spreads parallel with the incisor edge, soon resulting in coalescence. *(e and f)* In that way, a substantial part of the mesiodistal crown dimension is realized early. *(g and h)* After the crown is completed, the root is formed. *(a and b)* The mineralization of a canine (2) starts at one point and spreads under an oblique angle. *(c and d)* A large part of its mesiodistal crown dimension is realized early. *(e and f)* A canine reaches the stage at which the width increase becomes limited to approximal enamel deposition later than an incisor does. The root formation starts. *(g and h)* The pulp cavity becomes smaller by dentin deposition at the pulp chamber and the inner surface of the root. *(a and b)* The mineralization of a molar (3) starts at the mesiobuccal cusp and some time later at the other cusps. *(c and d)* The occlusal dimension of the crown increases until overall coalescence is attained. *(e and f)* The slopes between the cusps become flattened by enamel deposition. The circumference of the crown increases somewhat. *(g and h)* In multirooted teeth, the bi- or trifurcation appears. See video clips 3 to 6. (Printed from Van der Linden et al[3] with permission.)

Mineralization of canines starts at a single point. Their morphodifferentiation and mineralization lag behind that of the incisors and molars. The mineralization of canines spreads under an angle of about 45 degrees with the long axis of the future tooth. The increase in mesiodistal crown width occurs more slowly in canines than in incisors. Due to the differences in crown formation, the mesial and distal demarcations of deciduous molars and canines are reached at about the same time, week 28 after conception; in incisors, this occurs in week 20 (Fig 1-5).

Fig 1-6 Comparison of the enlargement of three deciduous teeth expressed in millimeters and percentages of the final width. The mineralization of the maxillary incisor starts in the 16th week postconception (pc) and is somewhat earlier than that in the mandibular first molar. The mesiodistal dimension of the incisor tooth bud is at that time 3.5 mm, which is 54% of its ultimate size. The corresponding values for the molar are 2.8 mm and 34.5%. In week 20, the formation of the incisor has proceeded to the extent that increase in crown width can only be realized by approximal enamel deposition. The canine starts to mineralize in week 20. Regarding the mesiodistal dimensions, the values reached in week 20 for the incisor, canine, and molar, respectively, are 4.5 mm and 69%, 2.6 mm and 42%, and 4.3 mm and 53%. In week 24, the mineralization starts in the molar at the second point. In week 28, the first coalescence is attained, and the canine has extended to the mesial and distal sides. From that moment on, increase of its crown width is realized only by approximal enamel deposition. D, distal; M, mesial; IC, initial calcification; C, coalescence. (Data from Kraus and Jordan[2] and Van der Linden et al.[4])



The increases in mesiodistal crown dimensions of a maxillary central incisor, maxillary canine, and mandibular first molar of the deciduous dentition are illustrated and compared numerically in Fig 1-6. Development of the incisor is clearly ahead of that of the two other teeth.

The mineralization of the mandibular deciduous teeth in five specimens at increasing developmental stages is presented in Fig 1-7. This figure also shows the relative sizes of the forming teeth within one specimen.

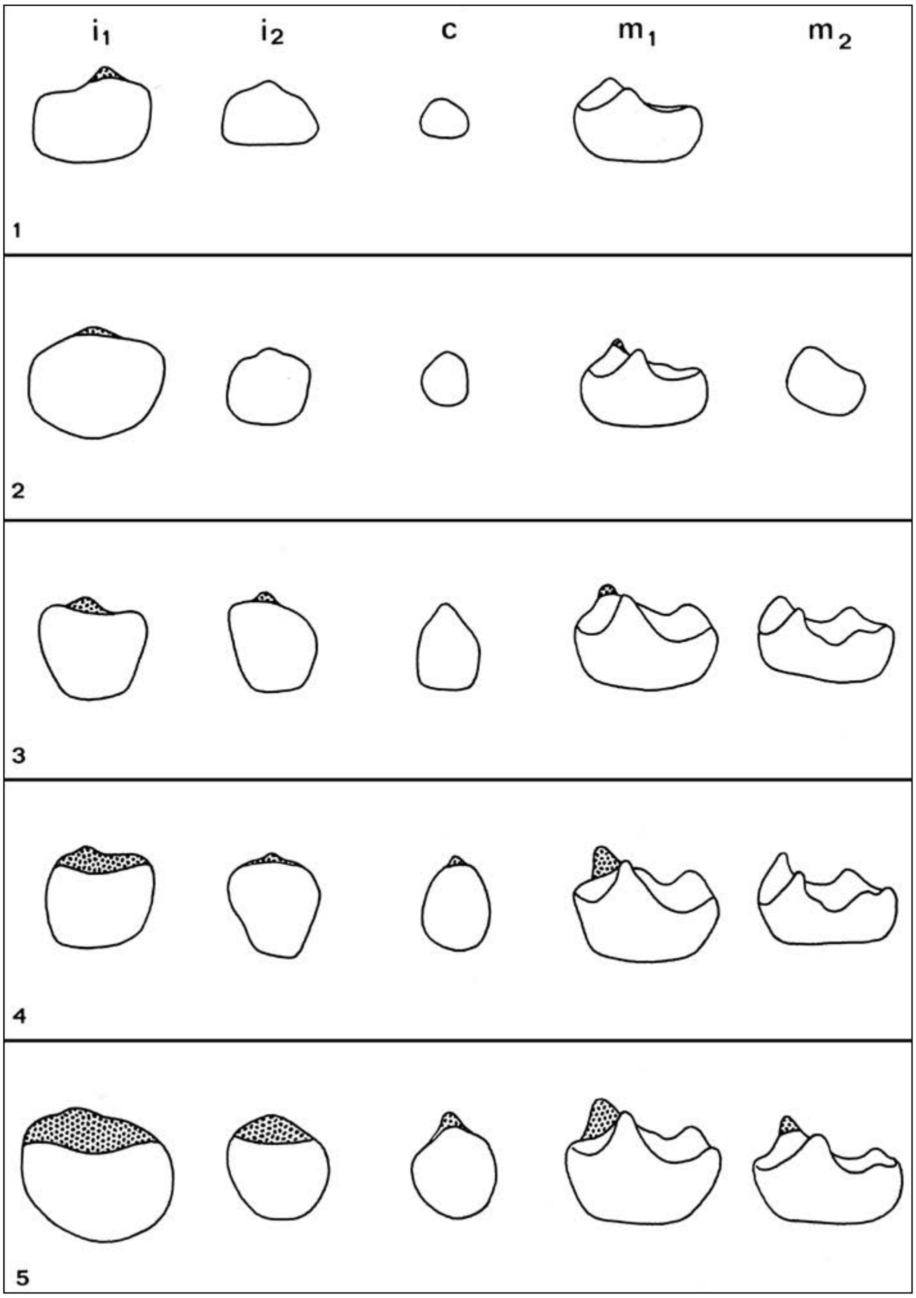


FIG 1-7 Mineralization of mandibular deciduous teeth. The [illegible] is based on five specimens at successive levels of development. The central incisor (i_1) is the first tooth that starts to mineralize, followed by the mesiobuccal cusp of the first molar (m_1). Subsequently, mineralization begins in the lateral incisor (i_2), the canine (c), and the second molar (m_2). All five teeth are mineralizing prior to the appearance of the second mineralization point in the first molar. The differences in size of the tooth buds in the separate series go back to the differential increase of dimensions in the five teeth. In assessing the five series, one must realize that differences in the ultimate size of corresponding teeth would have come about if their development had not stopped. These differences are not related to the level of development but based on the fact that some children have larger teeth than others. (Reprinted from Kraus and Jordan[2] with permission.)

Basic Properties of Teeth

Teeth have some typical properties. They are composed of the hardest tissues of the body. That applies particularly to the enamel. In comparison with other tissues, enamel and dentin are formed very slowly. For example, the mineralization of the first permanent molar starts before birth. When it emerges at 6 years of age, its root is not yet completely formed.

Deciduous teeth are formed more quickly than permanent teeth. The first deciduous tooth emerges at 6 months of age, the first permanent one at 6 years. A deciduous incisor has only slightly more than 1 year for its formation, while a permanent incisor has almost 7 years (see chapter 17 for details).

In accordance with the differences in time of their formation, deciduous and permanent teeth differ in composition and particularly in the density of enamel. The mineralization level of deciduous teeth is lower than that of permanent ones.[5] They have a whiter color (hence the name *milk teeth*), while permanent teeth have darker and yellower crowns. Because of the lower mineralization level, deciduous crowns are more susceptible to wear than are permanent ones. Deciduous molars lose their sharp cusp tips early.

In contrast to other tissues of the body, teeth cannot repair naturally. The parts of enamel and dentin lost by trauma or decay cannot be replaced. Enamel no longer can be deposited after the crown is completely formed. However, secondary dentin formation can continue on the pulpal side.

Tooth Positions During Development

Insight into the differences in the development of incisors, canines, and molars and of the deciduous and permanent teeth is essential for the understanding of the complex process of the development of the dentition. It is otherwise difficult to comprehend that deciduous and permanent incisors are formed in overlapping positions and that deciduous molars are formed one behind the other, without spatial limitations. On the other hand, second and third permanent molars are formed in a region where not enough space exists prior to the completion of jaw growth for them to be arranged one behind the other; therefore, they overlap.

References

1. Van der Linden FPGM, McNamara JA Jr, Radlanski RJ. Dynamics of Orthodontics: Facial Growth [DVD 2A]. Berlin: Quintessence, 2004.
2. Kraus BS, Jordan RE. The Human Dentition Before Birth. Philadelphia: Lea & Febiger, 1965.
3. Van der Linden FPGM, Radlanski RJ, McNamara JA Jr. Dynamics of Orthodontics: Normal Development of the Dentition [DVD 3A]. Berlin: Quintessence, 2000.
4. Van der Linden FPGM, McNamara JA Jr, Burdi AR. Tooth size and position before birth. J Dent Res 1972;51:71–74.
5. Schumacher GH, Schmidt H. Anatomie und Biochemie der Zähne. Berlin: VEB Verlag Volk und Gesundheit, 1972.

Index

Page numbers followed by “f” indicate figures; those followed by “t” indicate tables; those followed by “b” indicate boxes

A

B

C

D

E

F

G

H

I

J

L

M

N

O

P

R

S

T

U

W

Y